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AD283067
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DTIC 283067

R-341 - Final Report
Phase B - Part II
Contract: DA19-129-qm-1990
Truesdail Labs., Inc.

Optimal Water Storage Study of
Multifunctional Water-Commode Containers

Period: 30 April 1962 - 30 June 1962

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QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES
Research and Engineering Command
Quartermaster Corps, U.S. Army
Chicago, Illinois

<p>AD Accession No. _____</p> <p>Truesdell Laboratories, Inc., Los Angeles, Calif. OPTIMAL WATER STORAGE STUDY OF MULTIFUNCTIONAL WATER-COMMODE CONTAINERS - C. Bradley Ward, Jr., I. Bandziulis and C. L. Blohm</p> <p>Final Report, Phase B - Part II, 29 June 1962, 9 pp. 4 tables. (Contract DA19-129-QM-1990 (O.L.6076)). Project No. 2210.8 Unclassified Report.</p> <p>Data are presented on the storability of human waste in fiber drum containers lined with three different plastic films and containing four different sanitizers, over a period of 14 days. Adequate odor control was achieved with all sanitizers, i.e. soda ash, cresylic acids, saponified phenols and sodium pentachlorophenate, although soda ash showed no bactericidal action. Cresylic acids appear to be the preferred sanitizer. Among the liners, vinyl showed poor integrity, polyethylene and polyethylene-cellophane laminate showed marginal integrity. All plastics showed chemical compatibility with the waste.</p>	<p>UNCLASSIFIED</p> <p>1. Water Storage Study 2. Contract DA19-129-QM-1990 (O.L.6076)</p>
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CONTRACT RESEARCH PROJECT REPORT

QUARTERMASTER FOOD AND CONTAINER INSTITUTE FOR THE ARMED FORCES, CHICAGO
QM Research and Engineering Command, U. S. Army, QM Research and Engineering
Center, Natick, Massachusetts

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Project Nr. 2210.8
Contract: DA19-129-qm-1990
Report: (Final)- Phase B - Part II
File Nr.: R-341
Period: 30 April 1962
30 June 1962
Initiation Date: 30 April 1962

Title of Contract - Phase B - Part II: Human Waste Storage

29 June 1962

INTRODUCTION

This report is submitted in accordance with the requirements stipulated in Article 1 - Phase B - Part II of Contract DA19-129-QM-1990 (O.I.6076) entered into between the Quartermaster Food and Container Institute and Truesdail Laboratories, Inc. on April 30, 1962. Data are presented on storability of human waste, over a period of 14 days, in fiber drums lined with three different types of plastic films and the effect of four different disinfectants on control of gas evolution and odor. This is the final report on Phase B, Part II of the contract.

HUMAN WASTE STORAGE TESTS

LABORATORY EXPERIMENTS

In considering the problems of sanitization and odor control in the storage of mixed human waste, it was assumed that perceptible odor would be related to free gas formation. This assumption was predicated on the consideration that the plastic liners tested are all permeable, in some degree, to gases. Laboratory tests on liners showed that air penetrates the films at rates of one liter or more per square foot per 24 hours at only a few inches of water pressure above atmospheric. If no appreciable amount of free gas were developed, there would be no vehicle for transport of odors through the sealed liners. The vapor pressure of dissolved gases, such as ammonia, amines, and sulfur containing compounds, would be quite low and, therefore, provide little driving force for diffusion. In order, therefore, to conduct preliminary evaluations of proposed sanitizing agents, experiments were designed to measure gas formation as an index of effectiveness of the agent being tested.

Urine and fecal specimens from at least three people were collected and mixed the same day to a slurry containing approximately 6.5% solids, as calculated from average values given in "Practical Physiological Chemistry," 13th Edition, (Hawk, Oser, and Summerson). Any hard lumps were pressed or broken apart. Approximately 1.0% of invert sugar was then added to the slurry. As described in our proposal under this contract, previous experience in this laboratory had indicated that in order to always assure definite vigorous bacterial action in human excrement as evidenced by gas generation, it is necessary to furnish a substrate such as sugar, which is easily fermentable to carbon dioxide. If this is not done the gases formed, such as ammonia and hydrogen sulfide, which are appreciably soluble in aqueous solutions, dissolve to a large extent in the excrement slurry and visual observation of gas formation as a result of fermentation is difficult if not impossible. Furthermore, human excrements usually do not contain sufficient nutrients for bacteria to thrive, resulting in little or no gas generation. Since, as pointed out above, the odor problem in a confined area is tied direct to the formation of gas by bacterial action, addition of invert sugar as a bacterial nutrient was believed to be necessary to assure proper bacterial action. In this manner, more rigorous test conditions

were obtained, permitting evaluation of sanitizers under somewhat extreme conditions. Addition of sugar would also simulate situations where materials other than feces, such as vomit, may be introduced into the containers. A temperature of 86°F was used for incubation during the laboratory tests.

Various preservatives were added in varying amounts to portions of the excrement slurry, and from these portions, Smith fermentation tubes or tube-inverted-within-a-tube gas collectors were filled.

Five preservatives were tested: 1) Cr silicic acids (high boiling mixture), 2) phenol--soap mixture (50% phenol, 25% anhydrous soap, 25% inert), 3) soda ash (anhydrous sodium carbonate), 4) sodium pentachlorophenate (bead form), and 5) paraformaldehyde. The use of quaternaries, organic iodine compounds and materials of similar nature was considered but, in view of the high cost of these compounds and the need for high concentrations to obtain effective sanitation, they were not included in the tests. The soda ash was not readily soluble unless added to the container after the aqueous mixture had stirred. However, soda ash was selected rather than the more readily soluble hydrated sodium carbonate (washing soda) because of the extra weight of 10 molecules of water per molecule of sodium carbonate, and also because of the higher price of the washing soda. Paraformaldehyde and sodium pentachlorophenate were dissolved in the same manner as the soda ash. For the preservation of excrement in the 10-gallon drum tests (vide infra) 1.5 liters of tap water were added to each plastic-lined drum before addition of the preservatives.

An interesting phenomenon was observed during the laboratory fermentation experiments: In the absence of preservative, large amounts of gas were produced during the initial part of the fermentation period. This gas was largely reabsorbed by the excrement slurry during the later part of the fermentation period. This phenomenon may be explained by the following mechanism: During the initial stage of the experiment invert sugar was preferentially fermented with the formation of carbon dioxide which is sparingly soluble in the essentially neutral slurry. After the invert sugar was consumed, further fermentation of urea, proteins and other organic materials resulted in the formation of ammonia, amines and of some sulfur compounds, primarily hydrogen sulfide. Ammonia and amines react readily with acid gases such as carbon dioxide and hydrogen sulfide forming ammonium carbonate, bicarbonate, sulfide and the corresponding amine compounds, all of which are very soluble in water. Production of an excess amount of ammonia or amines over that of acid gas will, therefore, result in reabsorption of the carbon dioxide originally evolved. The validity of this hypothesis is evidenced, although indirectly, by pH values of 8.7 - 9.0 of the excrement slurry measured at the end of the experiment. Normal sugar fermentation results in final pH values below 7.0.

The results from two series of experiments, using separate controls, are shown in Tables I and II.

The inspection of the tables shows that early gas production was observed in the control tubes, followed by a disappearance of nearly all of the visually-observed gas phase. According to the mechanism discussed above, this does not indicate a subsidence of gas production, but rather an initial formation of carbon dioxide, followed by formation of ammonia, amines, etc. Without the addition of sugar to the excrement there would have been very little production of free gas, as was observed in preliminary unreported experiments. Daily gas readings were taken on fermentation tubes but to save space, only wider-spaced observations or those where changes occurred are presented.

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TABLE I

TABLE II

EXPERIMENT 1

EXPERIMENT 2

FERMENTATION OF HUMAN EXCREMENT

FERMENTATION OF HUMAN EXCREMENT

PRESERVATIVE: CONCENTRATION:		NONE (CONTROL)		NONE (CONTROL)	
Gas : 1		>15 ml.		1/ f t b	
Production: 2		1.5 ml.		3: entire	
at : 7		0.75 ml.		2/5 "	
Days : 14		0.3 ml.		1/4 "	
PRESERVATIVE: DILUTION:		CRESYLIC ACIDS - (PRODUCTOL)		CRESYLIC ACIDS - (PRODUCTOL)	
Gas : 1		1:40		1:160	
Production: 2		0		0	
at : 7		0		0	
Days : 14		0		0	
PRESERVATIVE: DILUT./CONC.:		CRESYLIC ACIDS - (ALLIED CHEMICAL)		PARAFORMALDEHYDE	
Gas : 1		1:40		1:2	
Production: 2		0		0	
at : 7		0		0	
Days : 14		0		0	
PRESERVATIVE: CONCENTRATION w/v%:		SODA ASH		SODA ASH	
Gas : 1		3		1	
Production: 2		0		2	
at : 7		0		0	
Days : 14		0		0	
PRESERVATIVE: DILUT./CONC.:		PENCILLS - SCAP		SODIUM PENTACHLOROPHENATE	
Gas : 1		1:60		0.2	
Production: 2		0		0.5	
at : 7		0		1	
Days : 14		0		1.5	

The results of the tests show that, under the laboratory conditions, all agents were effective over the ranges of concentration used except the para formaldehyde and the very low concentrations of soda ash. These data were used to set the concentrations to be used in the large scale drum storage tests.

DRUM STORAGE TESTS

The following materials were used in the drum storage tests:

Drums. One class of drum was employed, essentially in conformance to Specification MIL-D-43055 (QMC) 15 Jan. 1962. However dimensions were changed to conform to suggestion made in our original proposal viz., a total filled capacity of about 100-gals.

Class D: fiber sidealls, metal bottom, covered with fiber skirt and metal top.
Nominal dimensions: 13 1/4" dia. x 16' ht.
Obtained from Rheem Manufacturing Co., San Diego, California.

Liners. Three liner materials were used:

- 4 mil polyethylene (Dow Chemical Co.)
- 2 mil polyethylene - 0.9 mil cellophane laminate (Duckman Div. of Dow)
- 3 mil vinyl (VBA 9020 - Union Carbide)

All liners were fabricated essentially in conformance to Specification MIL-D-43056 (QMC) 15 Jan. 1962, but dimensions were altered to fit drum sizes used. All liners were approximately 24" x 34" flat. All liners were manufactured by The Richmond Corporation, Highland, California.

Mixed Human Waste. Obtained from and delivered by Modern Sanitation Co. of El Monte, California.

To get a satisfactory bracketing of preservative with two concentrations, the drum experiments, using a total of 52 drums, were set up in accordance with Table III. As mentioned above, 1.5 liters of water were placed in each drum before addition of the preservative. After sanitizing agent and invert sugar were added, the 10-gal. drums were filled about 2/3 full with the mixed human waste, the liners closed and tied tightly by twisting wire bag ties, and stored for observation. The waste consisted of collection made on 30 May at an air show, using portable toilets, and was untreated. The waste was transferred to a tank truck on the morning of 31 May, and delivered to the test site. The material was mixed in the tank truck by means of a circulating pump for about two hours so that it could be expected that the material was well mixed. It was delivered directly to the storage drums from the tank truck through a 3" hose spout.

The storage drums were inspected daily, except for the two days prior to the conclusion of the 14 day test, for odor and gas development. The odors from the controls were strong and offensive, becoming progressively more so as the storage period extended. Odors also developed from some of the sanitized drums although they could be detected only when the liners were inspected with the drum covers removed, and when one was quite close to the liner. All additives appeared to reduce odor intensity subjectively organoleptic evaluation referred to the controls by about 90% or more. From the drums containing soda ash, there was an organic amine or ammoniacal odor which also was observed with the containers employing pentachlorophenolate. The drums using saponified phenols had a fairly strong phenolic odor while the drums containing cresylic acids displayed a much weaker odor of the same type.

Final Report - Phase B - Part IIT A B L E IIIHUMAN WASTE DRUM STORAGE TESTS

D r u m L i n e r							
PRESERVATIVE	CONCENTRATION	POLYVINYL	POLYETHYLENE-CELLOPHANE			POLYETHYLENE	
		Numbers Below identify Total of 52 Drums Used[1]					
SODA	2.5% w/v [2]	1 [1]	2	3	4	5	6
ASH	3.0% w/v	7	8	9	10	11	12
CRESYLIC	1:750	13	14	15	16	17	18
ACID							
(PRODUCTOL)	1:160	19	20	21	22	23	24
5 % PHENOL +	1:480	25	26	27	28	29	30
25% OAP							
(SUPER-GRANITE)	1:160	31	32	33	34	35	36
SODIUM PENTA-	.1% w/v	37	38	39	40	41	42
CHLOROPHENATE							
(DOWICIDE G)	1% w/v	43	44	45	46	47	48
NE							
(CONTROLS)	--	49		50		51	52

[2] w/v weight volume = g/liter = lbs/12 gal = 0.83 lbs/10 gal.

NOTE 1 vrt sugar (50% sol'n) was added to every drum to give about 0.5% of sugar in the mixed waste.

Gas evolution was pronounced in the unsanitized control drums, during the initial period of the test. The same pattern as found in the laboratory experiments, viz., gradual disappearance of the generated gas during the later portion of the storage period was observed. This probably was due partly to reabsorption of acid gases by alkaline materials formed as the result of the fermentation of nitrogenous compounds. However, in view of the permeability of the plastic liners, some gas was undoubtedly lost by diffusion. Little or no gas generation was observed in the drums containing sanitizing agents.

Since the visual observation of gas formation and the organoleptic odor tests indicated rather high effectiveness of all sanitizing agents used, it was decided to analyse spot samples of the liquids after eight days of storage, in order to evaluate the bactericidal effect of the sanitizers. Such tests were not foreseen in the original work scope and, because of the limited time available for this phase of the project, only spot analyses could be made. The drums selected for sampling were Nos. 7, 12, 23 and 51. The first two drums contained 3% soda ash, No. 23 contained cresylic acid in 1:160 dilution and No. 51 was an unsanitized control. This selection was made to compare the effect of the soda ash, which is not considered a bactericide, and cresylic acid which is known to be a very effective bactericide. The analyses conducted included total bacterial count (Standard Plate Count Method of the American Public Health Association, 1960), anaerobe growth (Thioglycollate broth) and determination of residual invert sugar. In order to prevent carry-over of significant quantities of sanitizing agent to the growth medium the samples were diluted 1:10 before inoculation. The results of these analyses are shown in Table IV below.

TABLE IV

ANALYSES OF STORED HUMAN EXCREMENTS - AFTER EIGHT DAYS OF STORAGE

DRUM NUMBER:	7	12	23	51
PRESERVATIVE:	Soda Ash	Soda Ash	Cresylic Acid	None
PRESERVATIVE CONC./DILUTION	3.0%	3.0%	1:160	--
TOTAL BACTERIAL COUNT / ml @ 37°C	TNTC ¹	NTC ¹	Less than 10 (none found)	400
ANAEROBES-THIOGLYCOLLATE (30° & 37° C)	Growth	Growth	Uncertain ²	Growth
RESIDUAL INVERT SUGAR (about 1% originally added).	Trace	0	1.2%	0

[1] Too numerous to count at 1:10 dilution.

[2] No growth was found at 30°C and very few organisms found at 37°C.

The data presented in Table IV indicate that under the storage conditions cresylic acid (at a concentration of 1:160) is an effective sanitizer as evidenced by the finding of essentially no bacteria and the presence of all the invert sugar originally added after eight days of storage. This confirms the laboratory experiments. Soda ash on the

other hand, displayed little if any bactericidal action, but seems to have retarded the rate of fermentation, probably because of the high initial pH (11.0) of the solution. As carbon dioxide was gradually generated by slow preferential fermentation of the invert sugar--and was absorbed by the alkaline solution--the pH dropped to 9.3 (because of bi-carbonate formation) after 8 days of storage, providing a more favorable environment for bacterial growth than existed at the beginning of the test. If this mechanism is accepted the analytical data and the observations--i.e., little or no gas formation, low odor level, high bacterial count and disappearance of the invert sugar--can be explained.

The relatively low total bacterial count found in the unsanitized control drum can probably be explained by the well known fact that bacteria die gradually in a substrate devoid of utilizable nutrients and which may contain toxic bacterial waste products. There were four liner failures during the tests, one with laminated polyethylene-cellophane, three with vinyl. The polyethylene-cellophane liner failed on filling from mechanical rupture. The three vinyls failed after nine days, again by mechanical failure. All liners appeared to be compatible with the contents as far as chemical resistance was concerned.

Storage temperature never exceeded 75°F during the test period. Unfortunately, a temperature-controlled storage space was unavailable. It would be expected that a more elevated temperature would accelerate the biological activity, and might have some bearing on the observed results.

COSTS

Preliminary data have been obtained on the cost of sanitizing agents. Quantity-posted prices are listed below, followed by a tabulation of estimated cost ranges for actual use in 10-gal. containers.

SODA ASH, 58% Na₂O (American Potash & Chemical Co., Los Angeles)

20 ton Truckloads, bagged, \$35.00 per ton f.o.b. Trona, Calif.
bulk, \$30.00 " " " " "

CRESYLIC ACIDS, Grade 3837 (HIGH BOILING) (Productol Co., Los Angeles)

Carloads \$ 0.95 per gallon

SAPONIFIED CRESOLS (Super Germite, Standard Oil Co. of Calif.)

Carloads \$ 1.88 per gallon

SODIUM PENTACHLOROPHENATE (DOWICIDE G, Dow Chemical Co.)

20-30,000 lbs. \$ 0.26 per lb. (Flake, pellets, beads, powder).

Estimated Use Cost: 10-gallon Commodities

AGENT:	<u>SODA ASH</u>		<u>CRESYLIC ACIDS</u>		<u>SAPONIFIED CRESOLS</u>		<u>NaPCP</u>	
CONCENTRATION	2.5%	3.0%	1:160	1:759	1:160	1:480	0.1%	1.0%
COST, ¢	3.7	4.4	0.6	0.13	1.18	0.39	2.8	21.8

DISCUSSION and CONCLUSIONS

Sanitizing Agents: Results reported above indicate that all agents tested exhibited a reasonably satisfactory control over odor development under the test conditions which were more rigorous than can be expected in a fallout shelter. However, it is apparent from the sugar analyses and counts that the soda ash is really not a sanitizing agent. Control of odor by this chemical must largely be due to absorption of generated gas in the alkaline solution. This postulate is further verified by the fact that the pH dropped from 11.0 to 9.3 during the test period. On the other hand, it is quite apparent that the cresylic acids (and, presumably, theaponified phenols) definitely stopped fermentation and controlled odor under the rigorous test conditions. While the sodium pentachlorophenolate also appeared to be an effective agent, it may be discarded because of its dust toxicity in handling and its cost.

Therefore, in considering the variables of effective bactericidal action, odor control and cost, it would seem that the cresylic acids tested are the most desirable agent. The principal disadvantage of the cresylic acids is their corrosiveness to the skin when handled in concentrated form. However, assuming that the cresylic acid is supplied in easily-manageable containers and some instruction is given to the person responsible for disbursing of the agent, and that gloves and, possibly face masks or goggles are provided, it would not appear that this hazard is one of any substantial consequence.

Storage Containers: The suitability of the several plastic liners for waste storage under the conditions employed indicates that the polyvinyl liners have too low an index of integrity to be considered.

The polyethylene and polyethylene-cellophane laminate liners appear to be satisfactory as far as chemical resistance is concerned. However, in these cases also, integrity must be an important factor. The number of tests run do not provide a satisfactory statistical base for analysis, but one failure of the laminate liner in seventeen samples is certainly too high.

Finally, the permeability of all liners to gas diffusion and odor penetration appears to be too high. This factor could be of considerably greater magnitude if storage were to take place under higher temperature and humidity conditions as might be found in much of the United States under Summer conditions.

We can only conclude that none of the liner materials can be recommended firmly. The polyethylene is the most suitable from a compatibility and cost standpoint, and might be marginally acceptable.

The fiber drums with metal tops and bottoms appear to be quite satisfactory for the conditions prescribed, providing none of the liners leaks. The fiber drums will not contain leakage on their own.

The toilet seat model as delivered by the government appears to be satisfactory in general design. However, the hole should have the upper edges rounded. This seat could best be formed in quantity from pressboard or similar material, in which the hole and centering ring could be formed in the seat in a single die operation.

RECOMMENDATIONS FOR FUTURE WORK

Liners. Since the initiation of this project, new provisional military specifications for polyethylene bags, covering 2 mil double bags and 4 mil double bags, have been issued. While these specifications should contribute substantially to the mechanical integrity factor, they should be tested, particularly for gas and odor permeability. Of course, it is recognized that cost will be increased.

Currently, laminated films utilizing Mylar with other plastics and, in fact, triple laminates, including aluminum foil, are produced commercially. While their cost is high at present, such films have the advantages of strength integrity, and nearly zero permeability to gases. It would be desirable to test such films in comparison with the more recently specified polyethylene structures.

Although polypropylene films to date have not been readily available, the price of this material is diminishing, and more is entering the market. It might also be of interest to consider suitable formulations of such material.

Finally, we are aware of some work being done in the field of producing suitable lined drums. Certainly, as the liners become more elaborate and costly, integrally lined drums may become cost competitive for the required service. The utilization of such units certainly should be investigated.

Storage Conditions. As pointed out in the report, the storage tests were conducted at temperatures not exceeding 75°F in a well-ventilated room. Since fermentation processes are quite sensitive to temperature, significantly different results might be obtained at higher temperatures. It is, therefore, recommended that additional tests be conducted at controlled elevated temperatures. Furthermore, since ventilation has a considerable bearing on the odor level in a confined space, the additional tests should be conducted at confinement conditions simulating closely those to be expected in a fallout shelter.